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# News Briefs

## General Developments

*Inquiries about News Briefs, where no contact person is identified, should be referred to the Managing Editor, Journal of Research, National Institute of Standards, and Technology, Building 101, Room E215, Gaithersburg, MD 20899-2500; telephone: (301) 975-3577.*

### NEW VOLUMETRIC GAS FLOW STANDARD HAS REDUCED UNCERTAINTY

A new pressure, volume, temperature, and time (*PVTt*) primary gas flow standard for calibrating flowmeters has an expanded uncertainty ($k = 2$) of between 0.02 % and 0.05 %. This uncertainty is approximately five times better than the previously existing primary flow standards and elevates the NIST gas flow calibration service to "best in the world" status. The standard diverts a steady flow into a collection tank of known volume during a measured time interval. The standard spans the flow range of 1 L/min to 2000 L/min using two collection tanks (34 L and 677 L) and two flow diversion systems. The new standard has several novel features that contribute to its low uncertainty. The thermostatted collection tank allows determination of the average gas temperature to 7 mK (0.0023 %) within an equilibration time of 20 min. The system utilizes a mass cancellation procedure that reduced the uncertainty contributions from the inventory volume to 0.017 % at the highest flow rate. Flows have been measured independently throughout the overlapping flow range of the two collection tanks, and they agree within 0.015 %. The new flow standard is automated and computer controlled so after set up, the meter calibration is unattended by the operator.

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### SIMULATION AND MEASUREMENT OF A HEAD-DISK COLLISION IN MAGNETIC DATA STORAGE

Magnetic data storage technology has been following Moore's law, with data storage density doubling every 18 months. In the face of this, the National Storage Industry Consortium, now the Information Storage Industry Consortium, has set the ambitious goal of reaching 155 gigabit per square centimeter data storage in the next five years. For 155 Gb/cm$^2$ areal density technology, the head-disk interface becomes an important scientific and technological issue. The spacing between the head and the disk is shrinking to 3.5 nm with the disk spinning at speeds approaching 40 m/s. Occasional contacts will test the strength and robustness of the protective coating of carbon and lubricant on the disk, which are each only about a nanometer thick. Because of the reduced flight height, waviness of the disk, and rotational wobble, occasional contacts between the head and disk will occur, and sometimes catastrophically. Since this kind of random contact is difficult to measure and monitor, measurement tools are needed to simulate such events.

NIST has successfully developed an experimental technique and a numerical model to study the dynamic behavior of a head colliding with a disk. In the theoretical part of the study, a three-dimensional finite-element model was constructed to represent the overcoat, media and substrate, as well as a two-mass system, to represent the air-bearing slider. After solving the initial value problem, the model is capable of predicting the contact duration/frequency, contact forces, maximum penetration, energy dissipation and partition and underlying stress and deformation field for a given layered structure of the hard disk, asperity size and disk rotational speed.

In the experimental part of the study, a one-pass, high-speed impact test instrument and test method to evaluate materials responses on a hard disk surface have been developed. The basic concept is to artificially create a ridge (500 nm to 2000 nm height and 0.002° to 0.01° angle of incline) on the disk surface by controlled scratching on the substrate side of the disk to create a ridge on the top surface with its multilayer intact. A 3 mm-diameter ruby ball collides with the ridge at 7200 rpm rotational speed. The impact force is measured with an acoustic emission sensor and the deformation volume is obtained with an AFM.

The bench test and the simulation model lead toward the goal of providing the necessary tools to optimize materials, lubricants, and mechanical design for future high-density storage technology.
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## SUPERCONFORMAL ELECTRODEPOSITION USING DERIVITIZED SUBSTRATES

State-of-the-art manufacturing of microelectronics involves the electroplating of copper for on-chip wiring. Electroplating in the presence of organic additives enables seam-free and void-free filling of trenches and vias to create the horizontal and vertical "wires" of the integrated circuit. Recently, a simple two-step process has been developed by NIST researchers, which should allow deeper features to be filled with greater control over the process. These deeper features are critical for integrated circuits in the next five years.

The substrate is first "derivitized" with a sub-monolayer coverage of catalyst and then transferred for electroplating in a cupric sulfate electrolyte containing an inhibitor. When catalyst coverage is optimal, superconformal or "bottom-up" filling of trenches and vias is observed. If the catalyst coverage is too low or high, conformal or subconformal deposition occurs, resulting in void formation within the wires. The filling behavior of the derivitized features is quite similar to that obtained using a single (conventional) electrolyte containing both catalytic and inhibiting species. Success of the two-bath approach provides strong support for the "curvature enhanced accelerator coverage" mechanism (CEAC) of superconformal film growth developed at NIST. From a technical perspective, the two-step process offers an interesting solution to the difficult control issues associated with catalyst destruction and related aging effects known to occur in the "conventional" single-electrolyte superfilling process.
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## NIST UPDATES FEDERAL INFORMATION PROCESSING STANDARD (FIPS) FOR SECURE HASH STANDARD TO INCLUDE ADDITIONAL ALGORITHMS

On Aug. 1, 2002, the Secretary of Commerce approved FIPS 180-2, *Secure Hash Standard (SHS)*. The standard replaces FIPS 180-1, which was issued in 1992. FIPS 180-1 specified an algorithm (SHA-1) for producing a 160 bit output called a message digest. A message digest is a condensed representation of electronic data and is used in cryptographic processes, such as digital signatures, message authentication, and the generation of random numbers. FIPS 180-2 includes three additional algorithms, which produce 256 bit, 384 bit, and 512 bit message digests. These expanded capabilities are compatible with and support the strengthened security requirements of FIPS 197, Advanced Encryption Standard. FIPS 180-2 is available at http://csrc.nist.gov/publications/fips/index.html.
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## NIST PUBLISHES COMPUTER SECURITY GUIDELINES

NIST recently issued three new computer security documents, available at http://csrc.nist.gov/publications/nistpubs/index.html.

NIST Special Publication (SP) 800-40, *Procedures for Handling Security Patches.* Timely patching is critical to maintain the operational availability, confidentiality, and integrity of IT systems. However, failure to keep operating system and application software patched is the most common mistake made by IT professionals. To help address this growing problem, this special publication recommends methods to help organizations develop an explicit and documented patching and vulnerability policy and apply a systematic, accountable, and documented process for handling patches. The document also covers areas such as prioritizing patches, obtaining patches, testing patches, and applying patches. Finally, it identifies and discusses patching and vulnerability resources and advises on using certain widely available security tools.

NIST SP 800-46, *Security for Telecommuting and Broadband Communications.* This document is intended to assist those responsible for telecommuting security—users, system administrators, and management—by providing introductory information about broadband communication security and policy, security of home office systems, and considerations for system administrators in the central office. It addresses concepts relating to the selection, deployment, and management of broadband communications for a telecommuting user. It also recommends a series of actions federal agencies can take to better secure their telecommuting resources.

NIST SP 800-51, *Use of the Common Vulnerabilities and Exposures (CVE) Vulnerability Naming Scheme.* CVE is a dictionary of standard names for publicly known information technology (IT) system vulnerabilities that is widely supported in the public and private

sectors. This publication recommends that federal agencies make use of the CVE vulnerability naming scheme by 1) giving substantial consideration to the acquisition and use of security-related IT products and services that are compatible with CVE; 2) monitoring their systems for applicable vulnerabilities listed in CVE; and 3) using CVE names in their descriptions and communications of vulnerabilities.
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## A NEW SPIN ON CONDENSED-MATTER PHYSICS USING TWO-LEVEL ATOMS

The incredibly long coherence times of atomic hyperfine states make them ideally suited for frequency standards and quantum information processing. Recent experiments on quantum gases have utilized this cherished trait of cold atoms for the study of spin waves, a property usually associated with solid-state materials rather than dilute atomic gases.

NIST researchers have imaged the spatial structure of a standing spin wave for the first time in a dilute gas. The effect was seen in a gas of rubidium-87 atoms, cooled just above the transition temperature for Bose-Einstein condensation. NIST theorists teamed up with the experimentalists for a detailed study of the excitation frequencies and damping rates of the collective spin modes.

Their joint work was published in the Aug. 26 issue of *Physical Review Letters* [Phys. Rev. Lett. **89**, 090402 (2002)]. Details of the theory appeared in a separate article in *Physical Review A* [Phys. Rev. A **66**, 043411 (2002)]. This work emphasizes the crucial role that the internal coherence can play in collective properties of cold gases and has immediate relevance to the very active area of research on two-component Fermi gases.
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## LONG-TERM CARRIER-ENVELOPE PHASE COHERENCE ACHIEVED

NIST researchers have reported a significant extension of the laser technology being developed for optical frequency metrology and optical atomic clocks. While frequency-domain stabilization had heretofore been the chief concern, there are additional applications—in coherent control, signal proc-essing, and high-field physics—that also depend on long-term stabilization of the light field in the time domain. Recent measurements have demonstrated coherence times exceeding 100 s—corresponding to over $10 \times 10^{10}$ consecutive laser pulses—of the optical-frequency carrier wave with respect to its pulse modulation.

This work is based on ultrashort (femtosecond scale) pulses generated by mode-locked lasers. Light pulses this fast consist of only a few "wiggles" of the electromagnetic field, so the timing of the light wave relative to its pulse envelope is physically significant. Indeed, a repetitive train of such pulses is most useful when this phase relationship is maintained—and therefore, reliable—for extended periods of time. Previous research had focused on frequency-stabilizing the Fourier-transform of this complex optical signal, which appears spectrally as a "comb" of regularly-spaced spectral lines. However, for the additional target applications, the carrier-envelope phase coherence is more important. The new time-domain stability was achieved by using improved feedback loops and actuators in the mode-locked laser.

This work was reported in the Aug. 15 issue of *Optics Letters.*
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## SPECIMENS COLLECTED FROM PILOT WHALE STRANDING FOR NIST SPECIMEN BANK

On Monday, July 29, 2002, a mass stranding of 57 long-finned pilot whales (*Globicephala melas*) occurred in Dennis, MA, on Cape Cod. Strandings of marine mammals occur regularly at Cape Cod; how-ever, a stranding of this magnitude creates considerable activity among the scientific and volunteer personnel of the local stranding networks and aquariums, as well as tourists and the press. NIST scientists participated at the stranding site in the collection of tissue specimens from the whales for archival in the NIST National Biomonitoring Specimen Bank (NBSB). Since 1987, the NIST NBSB has participated in collecting and banking of tissues from marine mammals from U.S. waters of the Atlantic, Gulf of Mexico, and Pacific, including Alaska. The NBSB is designed to cryogenically preserve environmental and biological specimens over long periods of time (decades) for future retrospective analyses. A major activity of the NBSB is the National Marine Mammal Tissue Bank (NMMTB), established by Federal legislation in 1992, and maintained at the NBSB through partial support from the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS) and the U.S. Geological Survey, Biological Resources Division.

The NIST scientists worked with scientists and volunteers from the New England Aquarium, the Northeast Stranding Network, the NMFS and the Woods Hole Oceanographic Institute to obtain samples for inclusion in the NMMTB. Tissue specimens were collected from 11 animals that died on the first day of the stranding. Three late-stage pregnancies were found among the 11 whales, and tissue specimens were also removed from the three fetuses for a total of 14 animals sampled. Tissue specimens for the NMMTB are collected and processed following rigid standard operating procedures designed to reduce any contamination to the tissue. After processing, the tissue samples were immediately frozen and eventually stored in liquid nitrogen vapor freezers at the NIST NBSB satellite facility located at the Hollings Marine Laboratory in Charleston, S.C. These specimens, along with more than 2000 tissue specimens from over 715 other marine mammals already archived in the NBSB, will be used to determine not only the levels of contaminants in marine mammals but also the health of the marine environment. They will be available to scientists for evaluation for many years to come.

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## NIST CHEMISTRY WEBBOOK RECEIVES AWARD

The NIST Chemistry WebBook was voted the winner in the Portals and Information Hubs category of the "Best Chemical Sites on the Web" contest, sponsored by two private companies and the Royal Society of Chemistry, United Kingdom. These awards recognize unique and noteworthy Internet resources for chemists, chemical engineers, and chemical industry professionals in three categories: Online Courses and Tools, Portals and Information Hubs, and Corporate Sites. Web sites must be in English and free to users. An international panel of 16 distinguished editors and publishers, chemical information experts, librarians, chemists, and chemical engineers selected the winners from nominations of over 100 Web sites related to chemistry. There were 41 sites nominated in the Portals and Information Hubs category; the Corporate Sites category had 64 entries. The selection was based on the following criteria: accuracy, breath, and depth of content; usefulness; ease of use; and presentation. The announcement is on the Web at: http://www.chemindustry.com/contest/.

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## NIST PHYSICAL MODELS FOR CARRIER MOBILITIES TRANSFERRED TO INDUSTRY

Technology roadmaps from consensus-based planning efforts, such as the National Electronics Manufacturing Initiative (NEMI), stress the need for predictive physical models that describe carrier transport in compound semiconductors. As a response to this need, a NIST scientist calculated from quantum mechanical principles the electron and hole mobilities for the ternary compound semiconductors AlGaAs. The calculations will lead to better designs for bipolar transistors, in particular, the basis of such transistors. Also, productivity in the electronics industry will be enhanced because it is much cheaper to do mobility calculations than to do experiments on large numbers of samples with several values of doping concentrations and composition.

A private company, one of the best-known worldwide suppliers of software for simulating semiconductor processes and the performance of microelectronic and optoelectronic devices, inserted the mobility models into a device simulation tool by adding them in with sub-routine-like modules. Companies, universities, and government agencies use this device throughout the world to simulate and understand better the electrical and optical behavior of lasers, light-emitting diodes, power amplifiers (for the next generation of cell phones that can also receive digital video), and transistors. Further work is needed, however, because calculated mobilities for other ternary systems like AlGaN and quaternary systems like InAlGaN and InGaAsP are needed. The latter material systems are becoming very important for both commercial and defense applications (e.g., front ends of high frequency transceivers, LEDs, laser diodes, and other optoelectronics components) for use in high data rate telecommunications systems.

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## NEUTRONS EFFECTIVE IN PROBING MAGNETIC CLUSTER SIZES IN MAGNETIC RECORDING DISKS

The equivalent of Moore's law for magnetic recording is that the areal density of magnetically written bits increases at 60 % to 100 % per year. To achieve this, the noise in the magnetic media must be reduced continuously, which is accomplished by decreasing the size of the magnetic clusters—regions of the media that are magnetically coupled. The cluster size must decrease, since the media noise primarily results from the finite cluster size; the bit transitions are narrower

when the clusters are smaller. Presently, cluster sizes are believed to be about 10 nm to 15 nm, but accurate knowledge of the size distribution and even the average size is lacking. A common assumption is that the cluster size is identical to the crystalline grain size of the media, but this has not been demonstrated.

Recently, by carrying out small-angle neutron scattering (SANS) measurements on actual recording disks, scientists from a private company, working with researchers in NIST's Center for Neutron Research (NCNR), have demonstrated that this is indeed the case. The advantage that SANS provides is the ability to quantitatively separate the scattering due to the crystalline grains from the scattering that originates from the interaction of the neutron's magnetic moment with the net moment of the magnetic clusters. This was accomplished by first collecting data from disks that had been prepared to have the magnetic moments of the clusters randomly oriented. In this state, the SANS data contain contributions from the physical film structure (grains) and the magnetic film structure (magnetic clusters). Data then were collected while a large magnetic field was applied parallel to the disk surface. The field aligns the cluster moments (the sample effectively becomes one macroscopic cluster), and the remaining SANS is due to physical grain structure only. Subtracting the zero field and high field spectra leaves the desired magnetic SANS.

The SANS measurements showed that the magnetic cluster size scales with the grain size. Moreover, the intergranular magnetic interactions are not very strong, especially for the most advanced media tested where the cluster size was on average only about 10 % larger than the grain size. The measured cluster size distributions, however, were rather broad. The implication is that further reducing grain size to reduce magnetic cluster size will lead to higher recording densities if the size distribution of cluster sizes can be narrowed as well.

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## NIST'S COMPUTER FORENSICS TOOL TESTING PROJECT HELPS TO ASSURE THE ACCURACY OF COMPUTER FORENSICS INVESTIGATIONS

The first test report based on the Computer Forensics Tool Testing (CFTT) program was published by the National Institute of Justice at http://www.ojp.usdoj.gov/nij/pubs-sum/196352.htm. The test report documents results of testing dd GNU fileutils 4.0.36 provided with Red Hat Linux 7.1 and resulted in procedural changes in computer forensics laboratories across the country. NIST developed the CFTT to provide a measure of assurance that the tools used in computer forensics investigations produce accurate results. NIST researchers accomplished this by developing specifications and test methods for computer forensics tools. Currently, specifications are available for disk imaging and software write blocking tools. The test specifications and methods provide the information necessary for toolmakers to improve tools, for users to make informed choices about acquiring and using computer forensics tools, and for the legal community and others to understand the tools' capabilities. The NIST approach for testing computer forensic tools is based on well-recognized methodologies for conformance testing and quality testing.

The CFTT is a joint project of the National Institute of Justice, NIST, and other law enforcement agencies with participation from the broader computer forensics community. For more information, see www.cftt.nist.gov.

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## SPECTRAL RESPONSIVITY BILATERAL COMPARISON COMPLETED

NIST and the National Research Council of Canada (NRC) recently completed a bilateral comparison of routine spectral responsivity calibrations from 250 nm to 1800 nm, using silicon, germanium, and indium gallium arsenide photodiodes as transfer standards. The comparison was carried out to test the level of agreement for routine detector calibrations between the two laboratories and to support the uncertainties quoted by NIST and NRC in Appendix C of the Mutual Recognition Arrangement (MRA) drawn up by the International Committee of Weights and Measures (CIPM).

Excellent agreement was shown between the two laboratories. The differences between NIST and NRC were within the combined uncertainties throughout the spectral range. In particular, in the range 450 nm to 1000 nm, the agreement was within ± 0.2 %, and in the range 900 nm to 1600 nm, the agreement was typically ± 0.5 %. The results of this intercomparison were presented at the NEWRAD2002 conference, and will be published in the conference proceedings issues of *Metrologia.*

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## NIST HOSTS 12TH BIENNIAL SYMPOSIUM ON OPTICAL FIBER MEASUREMENTS IN BOULDER

Since 1980, optical fiber metrologists from around the world have gathered every other year at NIST in Boulder for the Symposium on Optical Fiber Measurements (SOFM), which covers measurement issues associated with optical fibers, related components, and optical communications systems. This year's meeting, held in September, came at a time when many companies in the optical telecommunications industry are struggling to survive. Even so, 145 scientists from 18 countries attended, and the number of paper submissions was up by about 50 % from the previous SOFM.

The high quality and diversity of topics of the papers presented made the conference especially useful. Popular topics included polarization-mode dispersion, non-linear behavior, fiber and waveguide geometry, group delay, dispersion, wavelength calibration, polarization dependence, multimode fiber properties, and systems modeling. The talks are summarized in four- to six-page papers included in the technical digest. The reference information is: P. A. Williams and G. W. Day, eds., *Technical Digest: Symposium on Optical Fiber Measurements, 2002,* NIST Special Publication 988 (2002). Copies of the Digest are available free of charge.

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## NIST DEVELOPS REFRESHABLE TACTILE GRAPHIC DISPLAY TECHNOLOGY

In cooperation with the National Federation of the Blind, NIST has developed a new refreshable tactile graphic technology that allows blind and visually impaired users to view images using the sense of touch. Unlike current devices that make a permanent record on plastic sheets or heavy-duty paper, the NIST device has a reusable surface made up of thousands of rounded pins that can display a succession of images without the cost and disposal problems of printouts.

This capability is highly important to users who need to view a large number of images or who need to be able to modify images. Future applications will include science, engineering, mathematics, education, and design (both technical and artistic) as well as the ability to view Web graphics. By using a passive pin locking mechanism, it is believed that this technology will make tactile displays possible initially in the range of $2000 to $3000, a factor of up to 20 less expensive than performing a similar function using conventional piezoelectric technology.

NIST has filed patents for the new technology and is in discussion with manufacturers to add the technology to their product lines. The website is http://www.itl.nist.gov/div895/isis/projects/brailleproject.html.

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## NIST-DEVELOPED ALGORITHMS REVEAL FUNDAMENTAL FLAWS IN COORDINATE MEASURING MACHINE FITTING SOFTWARE

NIST researchers recently presented new findings which indicate that serious problems can exist in some fitting algorithms used by commercial software packages. Coordinate measuring systems rely on embedded software algorithms to fit geometric shapes to measured points. At the October 2002 annual meeting of the American Society for Precision Engineering (ASPE), a NIST researcher presented alarming results demonstrating the problems discovered during a comparison between NIST reference results and results from commercial metrology software packages. For some geometric shapes and non-least-squares fit objectives, the algorithms used in the commercial software deviated from the NIST results significantly. The data sets used were representative of what might reasonably be encountered with many coordinate-measuring systems.

Since the whole measurement is only as good as the embedded software used, uncertainty with this software is cause for concern. NIST is making available reference pairs (data sets with their reference fits) that can be used by industry for comparisons with software packages. Reference pairs exist for one- and two-sided fit objectives for lines, planes, circles, spheres, cylinders, and cones. Documentation and additional reference data for fitting more general shapes (paraboloids, complex surfaces, etc.) are also available. NIST's special test service (NIST ATEP-CMS) provides tests for metrology software packages that use least-squares fitting techniques.

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## NANO-OPTICS FOR ATOMIC-SCALE OPTICAL RESOLUTION

Theoretical simulations have been performed at NIST to explain the extreme, atomic-scale optical sensitivity obtained in recent nano-optics experiments that probe atomic steps on silver surfaces.

Nano-optics is a rapidly emerging field of optics. One of its primary goals is the development of optical microscopy at the nanoscale. Nanoscale resolution

beats the wavelength-scale limits imposed by diffraction-limited, classical optics by a factor of 100. This super-resolution is critical for optical measurements of the nano/bioworld.

A multinational collaboration involving researchers at NIST, in Germany, and Sweden, investigated electromagnetic coupling on an atomic scale. Details were published recently in *Physical Review Letters.* Light emission from a scanning tunneling microscope was used to investigate the electromagnetic coupling between a metal tip and a metal surface. Experiments performed by our collaborators in Germany showed that atomic-scale modifications of the tip-sample region caused observable spectral shifts of the measured fluorescence. This exquisite sensitivity was demonstrated by probing a monatomic step on a silver surface and by variations due to atomic-scale changes in tip-sample distance. For sharp tips, the electromagnetic coupling was confined to a lateral range of a few nanometers, a factor of 100 better than the diffraction limit of conventional optics. The new calculations performed at NIST show that coupling between the probe and resonant plasmons localized at sample boundaries provide this atomic-scale optical sensitivity.

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## RESEARCHERS CONSTRUCT THERMODYNAMIC DATABASES FOR MULTICOMPONENT ALLOYS

Thermodynamic modeling allows the prediction of the phases present in complex alloys composed of many elements. Such phase equilibria calculations can be used to show composition, crystal structure, and volume fraction of the various phases, and can be determined from the extrapolation of thermodynamic descriptions of the constituent binary and ternary systems. Properties of a system, such as phase boundaries and enthalpies are described with one set of functions resulting in a consistent description of phase properties. The approach gives reasonable predictions for complex alloys and provides a compact storage method for massive amounts of phase diagram data.

Researchers at NIST have constructed a thermodynamic database for Ni-base alloys. The NIST Ni-superalloy thermodynamic database includes 10 elements, Ni-Al-Co-Cr-Hf-Mo-Re-Ta-Ti-W and describes properties of the liquid and the two most important solid phases, $\gamma$ and $\gamma'$. Data were derived from both critically evaluated literature and NIST work. As a result of this work, detailed solidification behavior for Ni-base superalloys can be predicted. This capability is now being used by the casting industry to shorten the development process.

The same methodology was used by the researchers to develop a thermodynamic database for solder alloys. This database includes seven elements, Sn-Ag-Bi-Cu-In-Pb-Sn, and has been used to evaluate freezing ranges for new environmentally friendly, lead-free solders, as well as the effects of potential Pb contamination of these solders.

Electronic versions of the NIST thermodynamic databases have been distributed to various industries, universities, and national laboratories and are available from the Web site http://www.metallurgy.nist.gov/phase/. This Web site also features a series of calculated binary and ternary phase diagrams for solder alloys as well as examples of the application of phase equilibria information to practical problems.

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## CARBON NANOTUBES INFLUENCE MATERIALS PERFORMANCE

Researchers from NIST, Purdue University, the University of Cincinnati, and the U.S. Air Force measured the arrangement of carbon nanotubes in suspensions in an effort to better understand their effect on the physical properties of the composite materials. Currently, the elastic modulus is improved by 100 % for nanotube-reinforced materials with 5 % reinforcement loading. At this level of loading, however, increases of the order of 1000 % can be expected. Although it is well known that the morphology of reinforcing agents has a direct influence on the performance of composites, the morphology of nanotubes in liquid suspensions or in polymer matrices is not known. This lack of understanding is at least partly responsible for the failure to realize the potential performance of nanotube-reinforced materials.

To address this need, small-angle x-ray scattering measurements on the NIST-responsible instrument at the Advanced Photon Source were used to interrogate the morphology of single-walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWNTs) in suspension. For MWNTs, the scattering was consistent with a rod-like morphology in which individual nanotubes were aligned in bunches with an overall diameter of approximately 500 nm. For SWNTs, a rod-like scattering profile was not observed on any length scale from 1 nm to 50 mm. Rather, disordered objects were found that were identified as a network of carbon "ropes". This arrangement of

SWNTs apparently reduces the ability of the nanotubes to improve the mechanical properties of composite materials and is suspected to be the reason for the large difference between theoretical predictions and the measured properties.
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## MOLECULAR-ELECTRONICS THEORIST PROPOSES MECHANISM FOR MOLECULAR SWITCHES

A NIST researcher has proposed a mechanism for the negative-differential resistance (an electrical off-on switching behavior) that has been observed in devices made from conjugated organic compounds.

The model is based on first-principles, quantum mechanical calculations that follow the changes in the electron clouds surrounding the molecular backbone when a voltage is applied across a molecule. The calculations indicated that the application of the bias voltage caused a substantial charge density rearrangement. This behavior was only observed in compounds that had been chemically modified by attaching an electron-withdrawing group somewhere in the middle of the molecule. This functional group acted as an electron basin, which makes the system act like a quantum well, trapping electron density between two barriers (in the case of a device, a molecule between two electrodes). A conductance model that used these calculations as input predicted switching at the voltage at which it had been observed.

The value of an idea, it has been noted, lies more in what it can predict than in what it can explain. With this principle in mind, the approach outlined above was used to find other compounds that exhibited the type of voltage-dependant charge rearrangement that had been found in compounds exhibiting negative-differential resistance. A compound, with the not-so-easy to remember name of 2-fluoro-4-phenylethynyl-1-[(4-thiol)-phenylethynyl]-benzene, has been predicted to possess the desired switching behavior. Collaborators have synthesized this new compound, and NIST researchers will soon be testing its electrical properties in silicon-oxide device prototypes.
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## NIST RELEASES ENHANCED VERSION OF AIRFLOW AND INDOOR AIR QUALITY MODELING SOFTWARE

NIST has released CONTAMW, a multi-zone airflow and contaminant transport simulation program. It can be used to assess the adequacy of ventilation rates in a building, to estimate the impact of building envelope tightening efforts on infiltration rates, and to predict contaminant concentrations to estimate personal exposure based on occupancy patterns in the building being studied. New features of the program include: the ability to control HVAC airflows based on temperature, pressure and contaminant concentrations, the ability to simulate non-trace contaminants such as water vapor, and to solve larger scale problems through an enhanced numerical solver. CONTAMW is available for download on the Web at www.bfrl.nist.gov/IAQanalysis.
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## NIST RESEARCHERS REPORT SPECIAL TEST OF HIGH-SPEED PHOTORECEIVER TO 110 GHz

NIST researchers have provided the first special test of the modulation response magnitude and phase of a commercially available photoreceiver to 110 GHz. High-speed photoreceivers are commonly used in fiber optic test equipment and communications systems operating at bit rates up to 40 Gbit/s. Measurement of both the magnitude and phase response of a photoreceiver over a frequency range much larger than the receiver's bandwidth is necessary for accurately modeling its response in the time-domain, thus providing critical information for digital communications systems. Prior to this work, calibration of the magnitude response above 50 GHz was not available, and calibration of the phase response was not available at any frequency.

The NIST researchers developed an electro-optic sampling system to perform the measurements. The system uses the electro-optic effect to sample high-speed electrical waveforms on a coplanar waveguide with ultrashort laser pulses. The researchers used standard microwave techniques to calibrate the response of the photoreceiver at its 1 mm coaxial electrical port, which was physically removed from the sampling plane on the coplanar waveguide where the waveforms were measured.

Using knowledge of the fundamental physics of the electro-optic sampling system, the NIST researchers have determined a preliminary uncertainty analysis of the system. The analysis showed typical expanded uncertainties (95 % confidence) less than 3° for phase and 0.4 dB for normalized magnitude. They checked the measurements and uncertainty analysis by comparing the results to the magnitude measured by a heterodyne method up to 50 GHz; the agreement was well

within the combined uncertainty of the two measurement systems.
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## CRYOGENIC CAPABILITY ADDED TO NIST's PULSED INDUCTIVE MICROWAVE MAGNETOMETER

NIST's recently developed Pulsed Inductive Microwave Magnetometer (PIMM) has now been enhanced with variable temperature capability. The new instrument can measure the magnetodynamic response of magnetically soft, thin-film materials at temperatures from 25 K to 325 K. In addition, the CryoPIMM has been augmented with high-field magnets that can apply dc bias fields up to 45 mT, permitting the study of materials with high anisotropy, such as single-crystal films of iron and nickel.

Built at NIST-Boulder, the CryoPIMM will be a powerful new tool to investigate the fundamental origins of precessional damping in thin metallic films. Most magnetic materials with a high permeability also exhibit under-damped response when driven with rf fields. The origin of the oscillatory response stems from the gyromagnetic properties inherent in all ferromagnets. The magnetic moment of the electron is fundamentally coupled to the quantum mechanical spin angular momentum: when a torque is applied to the magnetization, the intrinsic response of the electron moment is precession, much like how a gyroscope precesses under the influence of the Earth's gravitational field. However, in sharp contrast to a mechanical gyroscope, the angular momentum of the electron spin precesses at megahertz to gigahertz frequencies. In the absence of any coupling between the electron spins and the rest of the crystal environment, the precession would continue indefinitely. In reality, the spins are coupled to the atomic lattice such that the precession is eventually damped. Nevertheless, the resulting oscillations of the magnetic moment can be deleterious in practical applications, such as magnetic data storage. For example, the data rate in commercial disk drives is now approaching 1 Gbit/s. Disk drive engineers must be careful to avoid effects stemming from gyromagnetic precession at these frequencies. Most importantly, there is a need to determine sources of damping, with the goal of controlling the damping as a material design parameter.

There are multiple conflicting theories for damping in metallic thin films. One is "magnon-electron scattering" or "sd-exchange." This theory predicts a strong temperature dependence in the range of 4 K to 100 K. Observation of a temperature dependence in the damping would be strong confirming evidence for the sd-exchange theory.
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## INTERNATIONAL COMPARISON OF TEMPERATURE COMPLETED

Key comparisons, organized by the consultative committees of the CIPM, have the purpose of quantitatively establishing the level of agreement between the national measurement standards of signatories to the Treaty of the Metre, forming the basis for reducing technical-barriers-to-trade, and easing access by U.S. companies to global markets.

NIST staff recently completed work on Key Comparison 3 of the Consultative Committee on Thermometry (CCT-K3), which compares realizations of the International Temperature Scale of 1990 (ITS-90) over the industrially important temperature range −189 °C to 660 °C. Within this range, measurement accuracy of temperature is critical in industrial applications that include semiconductor processing, metallurgical processing, defense applications, and meteorological monitoring. This comparison, with NIST as a pilot laboratory, had a very large number of participants—15—and required the use of delicate thermometric fixed-point cells and standard platinum resistance thermometers. These factors increased the complexity of the execution and analysis of the comparison. In fact, no equivalent international comparison has ever been undertaken.

NIST staff developed and characterized transfer standards, performed the extensive and demanding measurements required of the pilot laboratory, and developed appropriate statistical methods for the analysis of the comparison. The final results revealed that the NIST measurements possessed a very high level of internal consistency that facilitated comparison of results from other participating laboratories.

The final report of the comparison has been approved by the CCT, and an abridged version has been published in *Metrologia* magazine. Within these documents, the differences in the realizations of the various fixed points in this range of the ITS-90 and the uncertainties of those differences are given for the 15 standards laboratories participating in the comparison.
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## NIST PERFORMS FIRST COMPARISON OF THE GAMUT ASSESSMENT STANDARD WITH OTHER NMIs

A NIST scientist conducted interlaboratory color measurement comparisons with the National Physical Laboratory (NPL) of the United Kingdom and the National Research Council (NRC) of Canada. These measurement intercomparisons among national metrology institutes (NMIs) and the NIST Display Metrology Project kick off the first phase of interactions aimed at reducing the variability of color gamut and other measurements used to characterize and specify performance of electronic displays. A key feature of the project is the development by NIST of a standard illumination source fitted with color filter artifacts se-lected to test the instruments and methods used in display measurement. The device, the Gamut Assessment Standard (GAS), will initially be circulated among additional NMIs, instrument manufacturers, and industry laboratories to evaluate the measurement variability of the display industry. Later, the device will form the basis of a NIST-calibrated transfer standard—Display Measurement Assessment Transfer Standard (DMATS), allowing industry laboratories to evaluate their measurement procedures and instruments.
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## NIST REMEMBERS THE FIRST COMPUTER

The early National Bureau of Standards (NBS) Electronic Automatic Computer (SEAC) was the first electronic computer in the United States to store programs internally. Designed, built in 1950, and operated at NBS by engineers, scientists, and mathematicians, it was the first of three computers built at NBS. Russell Kirsch, one of the original designers, met with several of the federal government engineers who participated in designing SEAC to share their memories of this historic event. Kirsch interviewed three of his fellow colleagues. A streaming video of this interview will appear soon on the NIST Web.
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## NIST's Jin RECOGNIZED BY *Discover Magazine*

In its November issue, *Discover Magazine* has recognized Deborah Jin of NIST as one of "The 50 Most Important Women in Science." Jin was cited for her pioneering work in creating fermion quantum gases.

Like Bose-Einstein Condensates (BECs), fermion gases consist of a large number of quantum constituents at the lowest achievable temperatures. However, the fermions, opposite the bosons in BECs, are constrained to all be in different quantum states. The results can shed light on other many-body systems, such as superconductors. This work is carried out at JILA.
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## FOR STATE-OF-THE-ART SUPERCONDUCTORS, NIST INVESTIGATES THE MECHANICAL BEHAVIOR OF RABiTS

One of the major challenges facing the development of an economical, practical, high-temperature superconductor has been the extremely weak mechanical behavior of Y-Ba-Cu-O coated onto rolling-aligned biaxially textured substrates (RABiTS). The RABiTS process is of great interest because it has the potential to be easily scalable to fabricate industrial quantities of this promising superconductor.

In the past several months, a private company has produced a new RABiTS coated conductor with substrates made of nickel plus 0.05 mass fraction tungsten. NIST scientists have completed a series of experiments using their specialized equipment for both transverse stress and transport current to measure the electromechanical performance of this new coated superconductor.

The results are striking. The NIST data show that in repeated testing the critical current (the maximum current the conductor can carry) is degraded by only 1 % to 5 % at the benchmark 100 MPa stress level. This result is one of the keys for opening the path for commercialization of RABiTS coated conductors. Projections are that this conductor could be manufactured at about $10 per kiloamperemeter. This cost would be competitive with copper in transformers and in other electric utility applications, and far less expensive than copper for increasing the capacity of underground transmission lines in urban areas.

Until now, the RABiTS process had worked only with soft, pure nickel substrates. Earlier NIST measurements showed that the critical current with nickel substrates degraded by as much as 28 % at the benchmark 100 MPa stress level, which made it unacceptable for use as a practical conductor in many applications.

NIST's electromechanical test capability for superconductors is one of the few test facilities of its kind in the world, and the only one providing specialized measurements for United States superconductor manufacturers.
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### NEW DEVELOPMENTAL TOOL FOR HIGH-EFFICIENCY LIGHTING BEING USED

There are an estimated 1 billion plasma light sources in service in the United States, consuming an estimated 600 billion kilowatt-hours (2 exajoules) of electrical energy annually. These sources principally include fluorescent lamps and metal-halide discharge lamps. In the past, metal-halide discharge lamps were used mainly for high-intensity lighting of large spaces, such as building exteriors and arenas. Nowadays, motivated by increased brightness and greater energy efficiency, metal halide lamps are also being developed for automobile headlights and regular interior lighting. As a result, there is a growing interest in increasing their luminous efficiency through a better understanding of the processes that govern their operation. However, these processes are so complex that they have defied attempts at predictive modeling or even development of scalable design rules. As part of a cooperative program with the Electric Power Research Institute (EPRI), NIST scientists have used the Advanced Photon Source at Argonne National Laboratory to observe x-ray absorption and fluorescence in the various elemental components of a metalhalide arc lamp. These new techniques provide a more complete picture of the arc, both spatially and chemically, than was possible previously. The observations permit NIST researchers to map the distribution of the halogen and metal ions in a production-style lamp. Such measurements lead to a better understanding of processes that affect the luminous efficiency of these lamps.

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### MEASURING LOCAL BIREFRINGENCE IN PHOTONIC MATERIALS

Novel polymer materials with structure on the scale of the wavelength of light, such as high-molecular-weight block co-polymers (BCs), have been noted for their potential use in photonic devices. These materials self-assemble to form spatial patterns that exhibit technologically useful optical properties for optical filters, couplers, and switches.

The promise of photonic BC systems underscores the importance of characterizing their local optical properties, since the optical activity of single microphase domains and defect structures may dictate device function. While traditional spectroscopic techniques and far-field microscopy, being inherently diffraction limited, are successful for measuring the bulk/ensemble optical characteristics of photonic materials, they do not have the spatial resolution required to map out these properties on the mesoscale. However, near-field scanning optical microscopy (NSOM), with its ability to generate optical micrographs with sub-diffraction limit resolution offers a means to accomplish such measurements. Combined with polarimetric techniques, this novel microscopy can be used to directly measure the birefringence and dichroism of thin polymer film samples with lateral resolution of about 50 nm.

Researchers at NIST have constructed a near-field polarimeter and have overcome a variety of measurement challenges to characterize the defect structures and to make quantitative measurement of the local birefringence of thin BC films. These measurements represent the first optical characterization of the domain structure of these novel materials.

This achievement is the result of a collaboration between NIST and researchers in materials science at MIT. The results of this work are published in a paper "Measuring Local Optical Properties: Near-Field Polarimetry of Photonic Block Copolymer Morphology," by M. J. Fasolka, Lori S. Goldner, J. Hwang, A. M. Urbas, P. DeRege, T. Swager, and E. L. Thomas, Phys. Rev. Lett. **90**, 016107 (2003).
CONTACTS: Lori Goldner, (301) 975-3792; lori.goldner@nist.gov or Michael Fasolka, (301) 975-8526; michael.fasolka@nist.gov.

## Standard Reference Materials

### NON-NEWTONIAN POLYMER SOLUTION FOR RHEOLOGY NOW AVAILABLE

A new Standard Reference Material, SRM 2491, is available for calibration of rheometers (instruments used to measure flow behavior of fluids). SRM 2491, a polydimethylsiloxane, is a companion standard to SRM 2490 for which NIST has certified the non-Newtonian theological properties. Polymer melts and solutions often demonstrate non-Newtonian flow behavior. Such fluids commonly have a viscosity that depends on the shear rate and display elastic effects like normal stresses that greatly affect their response to deformation. Accurate measurements of these material properties are critical for predicting the behavior of polymeric fluids in the complex flows they experience during processing and use. The two SRMs are intended to provide a means for comparing different methods of measuring viscoelastic fluid behavior.

For these fluids, NIST certifies the shear-rate dependence of viscosity and first normal stress difference

over a range of shear rates between $10^{-3}$ $s^{-1}$ and 100 $s^{-1}$, at temperatures of 0 °C, 25 °C, and 50 °C. The linear viscoelastic response is also certified, along with the shift factors, over the same temperature range.

There were several reasons for issuing a companion standard to SRM 2490. First, the zero-shear-rate viscosity of SRM 2491 at 25 °C is approximately one order of magnitude greater than the zero-shear-rate viscosity of SRM 2490. Secondly, the theological properties of the polydimethylsiloxane melt used for SRM 2491 exhibit less temperature dependence compared to the solution used for SRM 2490. This property could be advantageous in isolating transducer or actuator problems from temperature control problems in a rheometer. In addition, whereas SRM 2490 is a solution and subject to changes in properties with solvent loss, polydimethylsiloxane is stable and inert, and therefore should be free from any problems with chemical stability, evaporation, or safety.

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The main body of NIST SP 330 gives the essentials of the current form of the SI. However, Appendix 1 provides the Resolutions, Recommendations, and Declarations put forward on units of measurement and on the SI since 1889 by the General Conference on Weights and Measures (CGPM) and the International Committee for Weights and Measures (CIPM). Further, Appendix 2 summarizes the current state of the practical realizations of some important SI units, while Appendix 3 gives a brief description of the bodies established by the Meter Convention (the CGPM, CIPM, and BIPM), which was signed in Paris on 20 May 1875 by 17 States including the United States.

The 2001 Edition of SP 330 replaces its immediate predecessor, the 1991 Edition, which was based on the sixth edition of the BIPM SI publication. Like its predecessor, the 2001 Edition of SP 330 was edited by NIST physicist Barry N. Taylor.

Single copies of the 75-page NIST SP 330, 2001 Edition, may be obtained by contacting the NIST Metric Program, 100 Bureau Drive, Stop 2000, Gaithersburg, MD 20899-2000; telephone: 301-975-3690; fax: 301-948-1416; email: metric_prg@nist.gov. NIST SP 330 is also available online at the NIST Web site entitled "NIST Reference on Constants, Units, and Uncertainty," physics.nist.gov/cuu.

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